Dismantling Rubble Pile Asteroids with AoES (Area-of-Effect Soft-bots)

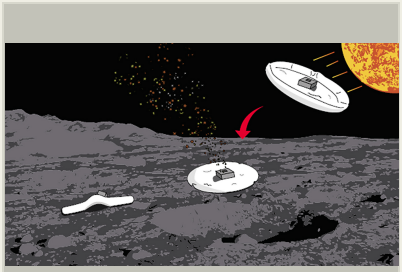
Completed Technology Project (2017 - 2018)

Project Introduction

This proposal seeks to develop a new type of soft robotic spacecraft which is specifically designed to move efficiently on the surface of, and in proximity to, rubble pile asteroids. These new spacecraft are termed Area-of-Effect Soft-bots (AoES) as they have large surface areas which enable mobility that is especially effective at small asteroids. The surface mobility is enabled by using adhesion between the soft robot and the asteroid surface. The adhesive forces also allow the AoES to anchor themselves in order to liberate material from the asteroid and launch it off the surface for collection by an orbiting resource processing spacecraft - forming the fundamental pieces of a resource utilization mission to a near-Earth asteroid (NEA). Furthermore, the large area necessary for the adhesion based mobility and anchoring also gives the AoES a relatively high area-to-mass ratio, enabling fuel-free orbit control using solar radiation pressure (SRP) forces. In total, this concept elegantly overcomes many of the difficulties typically encountered when trying to design a mission to retrieve a significant amount of material from an asteroid surface - in many cases using these perceived difficulties (e.g. microgravity, fast spin rates) to the advantage of the architecture. Development of AoES in order to make this mission architecture feasible therefore has the potential to drastically improve the capabilities of harvesting water and other resources from the variety of small, plentiful, easily accessible NEAs - enabling further exploration and economic profit in the solar system.

Anticipated Benefits

Development of AoES has the potential to drastically improve the capabilities of harvesting water and other resources from the variety of small, plentiful, easily accessible NEAs - enabling further exploration and economic profit in the solar system



Dismantling Rubble Pile Asteroid with AoES (Area-of-Effect Soft-bots) Credits: Jay McMahon

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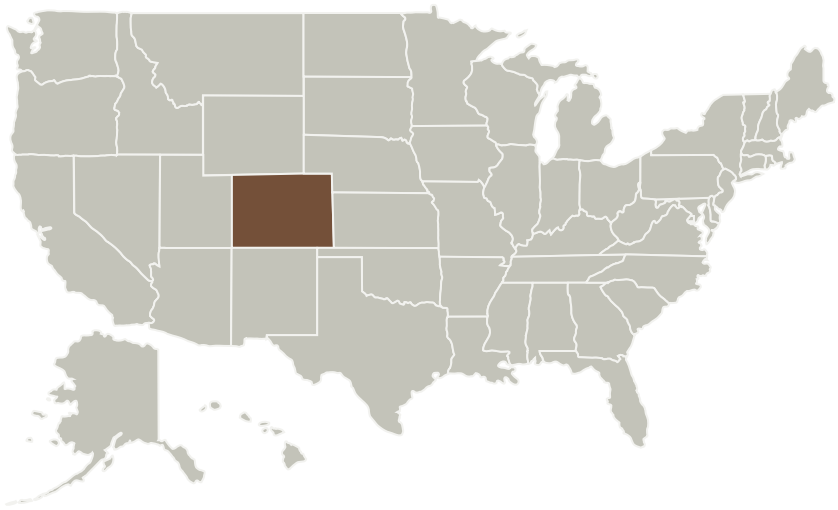
Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
University of Colorado Boulder	Lead Organization	Academia	Boulder, Colorado

Primary U.S. Work Locations
Colorado

Project Transitions

April 2017: Project Start

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

University of Colorado Boulder

Responsible Program:

NASA Innovative Advanced Concepts

Project Management

Program Director:

Jason E Derleth

Program Manager:

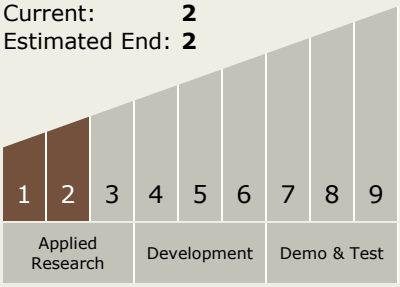
Eric A Eberly

Principal Investigator:

Jay Mcmahon

Technology Maturity (TRL)

Start: **1**
Current: **2**
Estimated End: **2**



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January 2018: Closed out

Closeout Summary: The Phase I study was focused on the major uncertainties in the basic feasibility of this concept, which fell into four categories: mission an d system design, mobility, actuation, and materials. The motivating questions fo r Phase I, and brief summary of the results are: Mission and System Design: Wh at are realistic size, power, mass, and shapes for the AoES? Basic system design s have been developed that produce an area-to-mass ratio in the range of 0.1-0.5 m2/kg. Mobility: Are the crawling, hopping, and landing processes possible a s imagined in the Phase I proposal? In short, yes. Computational mechanics mo del show that both crawling and hopping are possible. Simulations of orbit and h opping control leveraging SRP forces indicate signi cant controllability is availabl e with the area-to-mass ratios achieved in the system design. Actuation: Is it po ssible to actuate the soft robotic material as is necessary for the mobility concep ts we want? Do actuators with enough strength and control with realistic power exist? Will they function while dirty? This project has been greatly improved by c ombining forces with Co-I Keplinger to use his HASEL actuators. These actuators allow us to answer yes to all of the previous questions and provide significant fle xibility and performance in the AoES design. Materials: Are there any possible m aterials that can be used? Will adhesion exist for these materials? Can the mater ial be kept from turning to glass? Silicone elastomer has some heritage for spac e applications and is our leading material. While the question of adhesion remai ns open, our design now incorporates electroadhesion which means the need for naturally arising van der Waals adhesive forces is not as necessary for feasibilit y. Possible thermal control solutions have been identi ed but require more testin g. In short, our work has indicated that not only are there no major issues at thi s stage, but that there is even more promise to this concept than originally thou ght! However, there are still a number of outstanding questions that must be an swered to ensure concept feasibility: Is adhesive anchoring actually useable? Ca n HASEL actuators be used in space? Will the digging and launching process wor k as predicted? Can the soft robotic materials be kept at proper operating tempe ratures? Can the AoES actually be autonomously steered to arrive safely on the asteroid surface? Can the soft robotic leg designs actually be built and actuated? Given the promise and massive upside of this concept, we believe further resear ch and development should be directed toward the AoES concept.

Closeout Link: https://www.nasa.gov/directorates/spacetech/niac/2017_Phase_I_Phase_II/Area_of_Effect_Soft_bots

Technology Areas

Primary:

- TX07 Exploration Destination Systems
  - TX07.1 In-Situ Resource Utilization
    - TX07.1.2 Resource Acquisition, Isolation, and Preparation

Target Destination

Others Inside the Solar System

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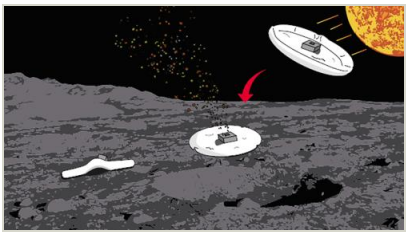
Images



Project Image
Dismantling Rubble Pile Asteroid with AoES (Area-of-Effect Soft-bots) Credits: Jay McMahon
(https://techport.nasa.gov/image/102194)

Links

NASA.gov Feature Article
(https://www.nasa.gov/directorates/spacetech/niac/2017_Phase_I_Phase_II/Area_of_Effect_Soft_bots)